A Deterministic Information-Based Model of Space-Time: The Universe as a Scanning Quantum Automation

Author: Shtepa Maxim
Status: Independent Researcher
Field: Theoretical Physics, Digital Cosmology
Contact: Shtepa.physics@gmail.com

August 31, 2026

Abstract

This paper proposes a novel conceptual framework that defines time not as a fundamental continuous entity, but as a discrete, predetermined sequence of spatial information states, designated as S-events [9.1]. We postulate an information field established prior to the Big Bang, which contains the complete structural and physical laws of the cosmos [6.1]. Within this model, the expansion of the Universe is mathematically formalized as a scanning process through this static informational matrix at a velocity $v(t)$ [9.1].

To eliminate limitations of anthropomorphic units associated with continuous dimensions (such as meters and seconds), we reformulate the system in a dimensionless quantum form [3.1]. The fundamental dynamics are governed by the differential equation:

$$dS = v(t)\, dt \tag{1}$$

where dS represents an exact number of discrete information bits (Planck-scale units) decoded by the expanding universe, and dt signifies the fundamental clock cycles of the cosmic evolution [8.1]. This approach inherently accounts for cosmological time dilation effects as a function of the shifting information density within accelerated frames of reference, aligning the deterministic block-universe view with the principles of digital physics [4.1, 6.1].

1 Introduction

The nature of time remains one of the most polarizing and unresolved dilemmas in modern theoretical physics. In classical Newtonian mechanics, time was treated as an absolute, continuous backdrop, flowing uniformly regardless of external spatial phenomena. However, the advent of Einstein's General Relativity fundamentally dismantled this paradigm, establishing that space and time are inextricably bound into a four-dimensional pseudo-Riemannian manifold [4.1, 7.1]. This relativity of simultaneity implies the existence of a "block-universe," a deterministic construct where the past, the present, and the future coexist with equal physical reality [4.1]. Within this geometric

framework, the intuitive human perception of a flowing "present" is exposed as a subjective illusion generated by biological consciousness, rather than an objective property of the cosmos [4.1].

Despite the geometric elegance of the relativistic block-universe, standard cosmological models introduce a critical paradox by treating space and time as infinitely smooth, continuous structures measurable in anthropomorphic units such as meters and seconds. In the subatomic realm, however, any attempt at continuous measurement is fundamentally constrained by Heisenberg's uncertainty principle, injecting statistical errors and observer-dependent fluctuations into the physical equations [3.1]. Yet, the cosmic lattice itself cannot operate on approximation. To resolve this contradiction, modern quantum gravity establishes the existence of the Planck length ($l_p \approx 10^{-35}$m) and Planck time ($t_p \approx 10^{-43}$m), which act as the absolute, indivisible pixels of reality [1.1, 8.1]. Consequently, any objective description of cosmic evolution must reject continuous dimensions and instead utilize a dimensionless, discrete informational framework where events are quantified as exact integers of computational bits [8.1]. Under this paradigm, physical space and its governing laws do not merely contain information; they emerge from a primordial configuration of data that precedes the spatial expansion itself [6.1, 10.1]. To unify the deterministic nature of the block-universe with the discrete, dimensionless requirement of quantum reality, this paper introduces a computational model of cosmic evolution [6.1]. We conceptualize the Universe as a scanning quantum automation moving through a static, pre-existing matrix of S-events, where each event represents a single bit of fundamental spatial data [9.1]. In this context, cosmic expansion is reinterpreted not as the physical creation of new space, but as the active decoding of this primordial informational array [10.1]. The core temporal dynamics of this system are mathematically formalized by the following differential equation:

$$dS = v(t)\, dt \tag{1}$$

where dS represents the exact integer number of discrete Planck-scale information bits decoded by the advancing cosmic horizon, dt represents the fundamental, error-free clock cycles of cosmic evolution [8.1], and $v(t)$ denotes the time-dependent velocity of the spatial expansion [9.1]. By integrating this relation, the total accumulated time becomes a direct function of the changing informational density within the accelerated cosmological expansion [8.1].

2 Mathematical Framework

2.1 Cosmological Integration

To analyze the dynamic behavior of the proposed information-scanning model, the fundamental differential relation must be evaluated across cosmological timescales. The core hypothesis dictates that the progression of time is an algorithmic manifestation of the Universe decoding discrete information bits (dS) at a time-dependent spatial expansion velocity $v(t)$ [8.1]. Since the velocity of cosmic expansion is non-uniform due to gravitational constraints and vacuum energy, the algebraic division of total quantities is physically invalid. Therefore, to determine the cumulative amount of decoded spatial data ($\sum S$) from the singularity event ($t = 0$) to an arbitrary cosmic epoch (t), we must apply the integration operator [7.1]:

$$\sum S = \int_0^t v(\tau)\, d(\tau) \tag{2}$$

where (τ) is the dummy variable of integration representing internal cosmic cycles, and $(\sum S)$ is a dimensionless, exact integer value counting the cumulative sum of decoded Planck-scale informational nodes [8.1]. Geometrically, equation (2) states that the total volume of processed reality is strictly equivalent to the definite area under the curve of the cosmic expansion velocity function.

To maintain absolute algorithmic and mathematical rigor, the differential components of equation (2) are strictly defined in terms of non-dimensionalized computational units. Here, the elemental spatial node displacement dS represents discrete bits of scanned system storage, the fundamental temporal step dt represents systemic processor clock cycles, and the scanning velocity $v(t) = dS/dt$ represents the local computational throughput expressed in bits per clock cycle, which is normalized to $v_0 \equiv 1$ in a pure quantum vacuum state.

To observe the dynamic behavior of the model in the real universe, we must introduce the realistic cosmological velocity function governed by dark energy. According to modern astrophysics, the late-stage cosmic expansion is exponential and defined by Hubble's law, where the velocity function is expressed as $v(t) = v_0 \cdot e^{Ht}$ [5.1, 7.1]. Substituting this physical constraint into the integral equation (2), the cumulative sum of decoded S-events $(\sum S)$ yields:

$$\sum S = \int_0^t v_0 \cdot e^{H\tau}\, d\tau = \frac{v_0}{H}(e^{Ht} - 1) \tag{3}$$

Equation (3) reveals a profound cosmological implication. As cosmic time (t) advances, the total amount of processed spatial information scales exponentially [8.1]. Consequently, the fundamental clock cycles (dt) required to decode a single unit of reality (dS) must dynamically compress. This implies that within an accelerating universe, the density of time is non-linear, establishing a mathematical link between dark energy and the global informational arrow of time [5.1, 8.1].

2.2 Topological Constraints and Orientation

To ensure the global stability of the deterministic informational arrow of time, the topological structure of the underlying manifold must satisfy strict orientability criteria [9.1]. Let us evaluate a non-orientable spatial manifold, exemplified by a Möbius strip embedded in $\mathbb{R}^3$ [9.1]. In such a manifold, a continuous parallel transport of a geometric basis (tetrad) along a closed non-trivial loop ε_1 results in a sign inversion of the vector field normal to the surface [2.1, 9.1].

If we align the cosmic time coordinate (dt) with the inverted direction of this topological trajectory, the fundamental differential relation under a complete spatial cycle undergoes an asymmetric transformation [9.1]. Due to the strict antisymmetry of the maximum-rank volume form (dS), the integration over a non-orientable closed loop yields:

$$dS \to -dS \implies dS + dS = 0 \implies dS = 0 \tag{4}$$

Equation (4) proves a critical topological theorem within the proposed framework. If the universe possessed a non-orientable topology, the global informational matrix would experience catastrophic data cancellation (information annihilation) at the intersection nodes [9.1]. The collapse of the differential increment to zero $(dS = 0)$ physically forces the computational velocity to freeze,

halting the progression of time entirely [9.1]. Therefore, we postulate that the primordial configuration of data strictly restricts cosmic evolution to orientable manifolds, mathematically forbidding Möbius-type geometries to preserve the linear progression of reality [9.1].

2.3 Discrete Quantization of the Integral

To reconcile the continuous cosmological integration shown in equation (3) with the error-free requirement of the universe, we redefine the integral operator using the discrete cellular partition of the manifold [9.1]. Following the geometric methods of exterior calculus, any continuous integral of a maximum-rank volume form over a region U is fundamentally a macroscopic approximation of a finite sum of discrete spatial cells [9.1]. Let the continuous manifold be partitioned into indivisible, dimensionless informational nodes (Planck-scale cells) denoted as ΔS_i. The total accumulated volume of reality ($\sum S$) is therefore mathematically formalized as an exact, deterministic summation:

$$\sum S = \sum_{i=1}^{N} \tilde{\omega}(\Delta S_i) \tag{5}$$

where $\tilde{\omega}(\Delta S_i)$ represents the exact integer value of the maximum-rank differential form evaluated at each individual quantum cell [9.1], and N is the total number of processed computational cycles [8.1]. In this quantized framework, the approximation sign ($\approx$) used in macroscopic physics is eliminated, as ΔS_i represents the absolute lower limit of reality (the Planck limit) [1.1]. Consequently, the Universe does not perform continuous calculus; instead, it executes a precise, error-free arithmetic summation of discrete bits of data, establishing a perfect link between continuous cosmic expansion and digital physics [6.1, 8.1].

2.4 Lorentz Invariance of the Information Vector

To ensure compliance with Special Relativity, the scalar scanning relation must be refactored into a Lorentz-invariant tensor representation [8.1]. In a four-dimensional Minkowski spacetime, an arbitrary event is defined by the coordinate 4-vector $x^\mu = (ct, x, y, z)$, where $\mu \in \{0, 1, 2, 3\}$ [2.1, 7.1]. The physical dynamics of cosmic expansion are parameterized not by coordinate time t, but by the invariant proper time τ of a co-moving observer [7.1]. The four-velocity of the cosmic scanning horizon is expressed as:

$$U^\mu = \frac{dx^\mu}{d\tau} = (\gamma c, \gamma v_x, \gamma v_y, \gamma v_z) \tag{6}$$

where $\gamma = (1 - v^2/c^2)^{-1/2}$ is the relativistic Lorentz factor [7.1]. We introduce the covariant information scanning 4-vector V_μ, which in the co-moving cosmological rest frame isolates the scanning velocity constraint into the temporal component: $V_\mu = (\frac{v(\tau)}{c}, 0, 0, 0)$ [7.1]. The core differential equation (1) is therefore redefined via the invariant tensor contraction:

$$dS = V_\mu dx^\mu \tag{7}$$

Under a standard Lorentz transformation Λ_ν^μ, the coordinate differential transforms as $dx'^\mu = \Lambda_\nu^\mu dx^\nu$, while the information vector transforms via the inverse matrix $V'_\mu = \Lambda_\mu^\nu V_\nu$ [2.1]. The contraction yields $dS' = V'_\mu dx'^\mu = V_\nu dx^\nu = dS$, analytically proving that the total decoded informational content is an absolute scalar invariant independent of the observer's relative velocity [2.1, 7.1].

2.5 Coupling of Information Cells with the Energy-Momentum Tensor

To integrate the model with General Relativity, the discrete information density must be coupled to the distribution of mass-energy [4.1]. Utilizing the geometric properties of exterior calculus, the maximum-rank volume form dS is generalized to a curved spacetime manifold governed by the metric tensor $g_{\mu\nu}$ [9.1]:

$$dS = n(x)\sqrt{-g}\, dx^0 \wedge dx^1 \wedge dx^2 \wedge dx^3 \tag{8}$$

where $g = \det(g_{\mu\nu})$ [4.1], and $n(x)$ represents the local invariant information bit-density per unit of geometric volume [10.1]. According to the holographic and Bekenstein entropy bounds, the spatial accumulation of discrete data states is bounded by the local matter configuration [1.1, 10.1]. We establish a tensor field equation mapping the spatial variance of $n(x)$ to the stress-energy tensor $T_{\mu\nu}$ via Einstein's gravitational coupling constant $k = 8\pi G/c^4$ [4.1]:

$$\nabla_\mu \nabla^\mu n(x) = \alpha k T_{\mu\nu} U^\mu U^\nu \tag{9}$$

where α is a dimensionless scaling constant. In a static Schwarzschild metric where $g_{00} = -(1 - 2GM/c^2 r)$ [4.1], resolving equation (9) isolates the local time-scanning velocity:

$$v(t)_{\text{local}} = v_0 \sqrt{1 - \frac{2GM}{c^2 r}} \tag{10}$$

Equation (10) provides an informational derivation of gravitational time dilation [4.1]. The presence of mass-energy ($T_{\mu\nu}$) locally compresses the bit-density of the pre-existing matrix, forcing the universal processing automation to expend more computational clock cycles to decode space [4.1, 10.1].

To establish a rigorous hydrodynamic and conservation link between the discrete information density $n(x)$ and macroscopic mass, the framework utilizes the exterior calculus formulation of the continuity equation on arbitrary manifolds [9.1]. We define the dynamic conservation of the informational matrix under cosmic evolution via the Lie derivative $\mathcal{L}_{\vec{U}}$ along the 4-velocity vector field of the scanning horizon $\vec{U}$ [9.1]:

$$\left(\frac{d}{dt} + \mathcal{L}_{\vec{U}} \right) (n(x)\tilde{w}) = 0 \tag{11}$$

where $\tilde{w} = \sqrt{-g} dx^0 \wedge dx^1 \wedge dx^2 \wedge dx^3$ represents the invariant metric volume form of the manifold. Equation (11) dictates that the computational data stream is structurally constrained, preventing both information duplication and data loss during the sequential state transition [9.1]. Geometrically, the macroscopic parameter of "mass" or "energy density" is analytically reduced to the spatial volume of the localized information form [4.1, 9.1].

Applying the generalized Gauss-Stokes divergence theorem to equation (11) over a compact spacetime region U yields the integral formulation of data conservation [9.1]:

$$\int_U (\mathrm{div}_{\tilde{w}} \vec{J}_S)\tilde{w} = \int_{\partial U} n(x) d\tilde{\Sigma} \tag{12}$$

where $\vec{J}_S = n(x)\vec{U}$ is the information current four-vector, and $d\tilde{\Sigma}$ is the restricted $(n-1)$-form of the spatial boundary [9.1]. Equation (12) mathematically demonstrates that any local variance of matter-energy within the four-dimensional bulk (the left-hand integral) is strictly balanced by the net flux of discrete bits processed through the three-dimensional boundary of the macroscopic Present (∂U), validating the principle of Boundary Data-Driven Computation (BDDC) [9.1].

2.6 Operator Quantization and the Cosmological Hamiltonian

To completely eliminate continuous variables at the fundamental scale, the framework is mapped to a discrete Hilbert space of information states [3.1]. The dynamical state of the Universe is represented by the state vector $|\psi_n\rangle$ where $n \in \mathbb{N}$ represents the discrete clock-cycle count of the universal processor since the singularity [3.1]. The discrete pieces of space are modeled as quantum excitations in an informational Fock space [3.1]. We define the unitary cosmic scanning operator $\widehat{\mathcal{U}}$ that drives the step-by-step evolution of reality:

$$\widehat{\mathcal{U}}|\psi_n\rangle = |\psi_{n+1}\rangle \tag{13}$$

The total information bit-volume operator $\widehat{N}_S$ yields an exact integer eigenvalue representing the absolute count of decoded Planck-scale nodes [3.1]:

$$\widehat{N}_S|\psi_n\rangle = S_n|\psi_n\rangle, \quad S_n \in \mathbb{Z} \tag{14}$$

The discrete rate of information processing is governed by the cosmological information processing rate operator $\widehat{V}_{inf}$ [3.1]. In compliance with the Heisenberg equation of motion, the temporal derivative is replaced by the commutator with the cosmological Hamiltonian of the cosmos $\widehat{H}_C$ [3.1]:

$$\widehat{V}_{inf} = \frac{d\widehat{N}_S}{dt} = \frac{1}{i\hbar}[\widehat{N}_S, \widehat{H}_C] \tag{15}$$

To prevent computational data duplication and preserve the strict directional arrow of time, the information operator and the scanning operator must satisfy the fundamental commutation relation [3.1]:

$$[\widehat{N}_S, \widehat{\mathcal{U}}] = \widehat{\mathcal{U}} \tag{16}$$

To structurally validate the stability of this state transition against computational rounding errors and synchronization collapses, the operator framework is coupled with the Frobenius integration theorem formulated in exterior calculus (Schutz, 1980) [9.1]. The step-by-step application of $\widehat{\mathcal{U}}$ is isomorphic to the sequential foliations of a closed differential ideal generated by a set of independent one-forms $\{\tilde{a}_i\}$ [9.1]. The system remains mathematically consistent and integrable if and only if [9.1]:

$$\tilde{a}_i = \sum_{j=1}^{m} P_{ij} dQ_j \tag{17}$$

where each set of constant scalar invariants $\{Q_j = \text{const}\}$ maps directly to a smooth, isolated three-dimensional hypersurface of the macroscopic Present [9.1]. Equation (17) algebraically guarantees that the local computational states compiled by the scanning automation are strictly bounded within independent, non-intersecting foliations [9.1]. Consequently, the temporal progression (dt) avoids multi-valued logical traps and singularity bottlenecks, ensuring that the continuous macroscopic time-flow is derived deterministically from the exact, error-free arithmetic of the global algorithm [6.1, 9.1].

3. Result and Analysis

3.1. The Fallacy of the Observer and Quantum Superdeterminism

A critical challenge to any deterministic model of cosmic evolution stems from the standard Copenhagen interpretation of quantum mechanics, which posits that physical reality remains in a state of probabilistic superposition until collapsed by an act of measurement. The framework proposed in this paper fundamentally rejects this observer-centric paradigm by introducing a relativistic and quantum decoherence constraint on the act of observation itself [6.1].

To formalize this constraint mathematically, let us define the spacetime interval between the instantaneous quantum decoding event E_0 (at the Planck scale) and the macroscopic measurement event E_m registered by the observer. In a locally flat Minkowski metric, the invariant spacetime interval ds^2 is expressed as [2.1]:

$$ds^2 = -c^2dt^2 + dx^2 + dy^2 + dz^2 \tag{18}$$

For any physical signal (photons, gluons) propagating from the subatomic event E_0 to the observer's apparatus at E_m, the trajectory is strictly bounded by the light-cone condition, where $ds^2 \geq 0$ [2.1, 7.1]. Therefore, the absolute physical time delay Δt_{delay} between the actual state transition of the S-event and its macroscopic detection is governed by the spatial distance $\Delta r = \sqrt{dx^2 + dy^2 + dz^2}$ and the characteristic quantum decoherence time of the measurement apparatus Δt_{dec} [11.1]:

$$\Delta t_{\text{total}} = \frac{\Delta r}{c} + t_{\text{dec}} \tag{19}$$

Equation (19) establishes a fundamental inequality. Since $\Delta r > 0$ and $\Delta t_{\text{dec}} > 0$, the total detection time Δt_{total} is strictly non-zero. When the apparatus attempts to calculate the state change dS/dt, it is mathematically evaluating a retarded potential [11.1]:

$$\left(\frac{dS}{dt}\right)_{\text{observed}} = v(t - \Delta t_{\text{total}}) \tag{20}$$

Equation (20) analytically proves that the measurement system operates exclusively on historical, pre-decoded data [6.1]. The Copenhagen ‘‘wavefunction collapse’’ is thereby reduced to a mathematical artifact caused by the non-zero value of Δt_{total}, stripping the macro-observer of any active causal role in the instantaneous generation of reality [6.1, 11.1]. This interpretation is strongly supported by ’t Hooft, who demonstrates that quantum mechanics can be viewed not as a fundamentally probabilistic system, but as a mathematical tool for analyzing an underlying deterministic cellular automation [10.1]. Within this framework, the apparent ‘‘free will’’ of the observer is exposed as an

illusion, since both the particle and the measuring apparatus are bound by the same pre-calculated cosmic data matrix [11.1].

3.2. Cosmic Collapse and the Information Extinction Boundary

To evaluate the structural boundaries of the proposed model under extreme astrophysical scenarios, we must analyze the theoretical behavior of the informational matrix during a hypothetical cosmic collapse (the Big Crunch) [7.1]. While late-stage observations in our universe confirm accelerated expansion driven by vacuum energy, the mathematical limit of a closed, recollapsing spatial manifold provides critical validation for the core differential relation [5.1].

To analytically derive the behavior of the computational scanning velocity $v(t)$ during a cosmic collapse, we map the informational progression to the first Friedmann equation for a closed, matter-dominated universe where the spatial curvature parameter $k = 1$. The dynamical evolution of the cosmic scale factor $a(t)$, which geometrically defines the radius of the expanding or contracting spatial matrix, is governed by [5.1, 7.1]:

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{c^2}{a^2} \tag{21}$$

where $\dot{a} = da/dt$ represents the physical expansion or contraction velocity, G is the gravitational constant, and ρ is the energy density of the cosmic substrate [5.1, 7.1]. In our framework, the informational scanning velocity $v(t)$ is structurally isomorphic to the magnitude of the geometric rate of change of the scale factor, such that $v(t) \equiv |\dot{a}(t)|$ [5.1]. Isolating $\dot{a}$ from equation (21) yields:

$$v(t) = |\dot{a}(t)| = \sqrt{\frac{8\pi G}{3}\rho a^2 - c^2} \tag{22}$$

During the final phase of the Big Crunch, as the scale factor $a(t)$ monotonically contracts toward the absolute gravitational singularity, the spatial boundary approaches the critical turning point. At the asymptotic node of the conformal transition between consecutive cosmic aeons, the standard spacetime metric becomes physically divergent. To maintain computational continuity, the scanning automation executes a conformal gauge transformation of the metric tensor [5.1]:

$$\hat{g}_{\mu\nu} = \Omega^2(x) g_{\mu\nu} \quad (\Omega(x) \to \infty) \tag{23}$$

The conformal factor $\Omega(x)$ compactifies the boundary, forcing the total entropy of the contracting manifold to register as the initialization energy (E_{init}) of the subsequent cyclic era. Bound by Seth Lloyd's absolute memory threshold ($S_{max} = 10^{120}$ bits), this energy state marks the physical boundary regulated by the spatial domain operator dU [1.1, 8.1]:

$$E_{init} = S_{max} \cdot E_p \approx 2 \times 10^{129}\text{J} \tag{24}$$

Evaluating this contraction yields a deterministic initial energy bound of $E_{init} \approx 2\times10^{129}$J [8.1]. Consequently, the initial boundary conditions of the newly initialized era represent a precise informational invariant of the preceding aeon, preserving global data conservation across infinite conformal iterations [1.1, 5.1]. This rigid conservation of the boundary energy framework establishes the mathematical prerequisite for analyzing localized, non-local quantum-information transitions within the emergent spacetime bulk, as detailed in the subsequent section [1.1].

3.3. Nonlocal Quantum-Information Phase Space Transitions and Invariance of Symplectic Volume

Within the framework of the deterministic discrete model, the evolution of subsystems is governed not by the mechanical displacement of mass through a continuous manifold, but by a step-by-step address re-indexing within a global memory register of the Universe with a capacity of $S_{max} = 10^{120}$ bits [1.1, 8.1].

At the macroscopic level of SRT and GRT, this scanning process manifests as motion along the temporal leaves of the foliation $t = const$ (Foliation) [1.1, 9.1].

To implement an instantaneous space-like transition (non-local translation) of a subsystem from a local neighborhood $A(q_A)$ to a remote coordinate point $B(q_B)$ within a single clock cycle of the scanning frequency $\Delta t_{min} = \frac{\pi\hbar}{2E_{init}}$, a Coherent Quantum-Information Phase Space Translation Generator (CQI-PTG) operator is introduced [1.1]. The physical operating principle of the CQI-PTG is based on three fundamental geometric invariants:

1. **Isoentropy and Computational Reversibility (The Carathéodory Theorem):** To prevent a seasonal cascade failure or thermal death of the cosmic informational system due to the dissipation of Landauer heat $\Delta Q = k_B T \ln 2$, a non-local jump is encoded as a strictly reversible operation (Reversible Computing) [1.1]. The transition trajectory of the subsystem is constrained to an isoentropic hypersurface, which guarantees the conservation of the object's informational capacity [1.1, 9.1]:

$$dS = 0 \tag{25}$$

2. **Conservation of the Coscalar Product and Ertel's Invariant:** The materialization of the subsystem's wave packet at point B requires the complete conservation of its intrinsic quantum numbers (spin, angular momentum) and Landau probability amplitudes [3.1, 9.1]. The CQI-PTG reads the numerical Ertel invariant (scalar α) [9.1]:

$$\alpha = \frac{1}{\rho}\nabla S \cdot (\nabla \times V) = \frac{1}{\rho}\epsilon^{jkl} S_{,j} V_{k,l} \tag{26}$$

During address re-indexing, the local gauge transformation artificially reconstructs at point B such a distribution of information density ρ and vorticity $\nabla \times V$ under which the scalar α remains unchanged [1.1, 9.1]. This ensures the unitarity of the quantum transition $[\widehat{T}_{NL}, \widehat{H}] = 0$ and the continuity of conservation currents [3.1, 9.1].

3. **Canonical Compensation of Non-Tensor Connection Tails via Strong Equivalence:** Since the Christoffel symbols Γ^i_{jk} are not true tensors, an instantaneous change of the spatial coordinate basis generates a non-linear coordinate noise described by the transformation of the affine connection (Schutz, Sec. 6.13) [9.1]. Similarly, in accordance with the gauge geometry of the $U(1)$-bundle (Schutz, Sec. 6.14), a localized shift in the quantum wave function's phase $\psi \to \psi e^{i\varphi(x)}$ generates a non-tensor phase "tail" $d_\mu \varphi(x)$ that breaks the covariance of standard derivatives [3.1, 9.1].

To prevent the disruption of the Maxwell field structure ($d\tilde{F} = 0$) and ensure the strict validity of the calibro-covariant Klein-Gordon threshold [9.1]:

$$(D_\mu D^\mu - m^2)\psi = (\nabla_\mu - iqA_\mu)(\nabla^\mu - iqA^\mu)\psi - m^2\psi = 0 \tag{27}$$

the CQI-PTG utilizes an exponential mapping $\exp_P$ to initiate local Riemann normal coordinates at the target destination B, forcing the affine connection to vanish at the exact moment of materialization: $\Gamma^i_{jk}(B) = 0$ [9.1]. Concurrently, the non-tensor gauge "tail" of the $U(1)$ phase connection is expressed as [9.1]:

$$\tilde{A} \to \tilde{A} + d\varphi \tag{28}$$

This shift is automatically compensated by a structurally-determined phase modulation of the Dirac-Heisenberg wave function via Schutz's operator exponential law [3.1, 9.1]:

$$\bar{A}(B) = \exp[\Delta\vec{\lambda} \cdot \nabla_{mod}]\bar{A}|_A \tag{29}$$

Due to the symmetry of second partial derivatives and the internal antisymmetry of the exterior volume form $\tilde{\sigma} = \tilde{\omega} \wedge \cdots \wedge \tilde{\omega}$, all parasitic coordinate and gauge divergences identically annihilate ($d\tilde{\sigma} = 0$, ($d^2\varphi \equiv 0$) [9.1]. The subsystem seamlessly integrates into the local geodesic deviation equation of point B ($\nabla_{\vec{U}}\nabla_{\vec{U}}\vec{\xi} = \mathbf{R}(\vec{U}, \vec{\xi})\vec{U}$), continuing its stable evolution in strict accordance with the global superdeterministic crystal of the Universe's macro-events [1.1, 9.1].

4. Discussion and Conclusion

4.1. Systemic Feedback Risks and Local Causality Inversion

The operational architecture of the proposed Coherent Quantum-Information Phase Space Translation Generator (CQI-PTG) introduces a fundamental paradox within a strictly deterministic, superdeterministic cosmic automation [1.1]. At the microscopic level of standard gauge-covariant fields, an instantaneous space-like transition via address re-indexing manifests as a localized inversion of standard causality vectors. If executed as an unconstrained, non-unitary perturbation, such non-local translations pose a critical systemic feedback risk to the global processing grid. The abrupt disruption of local quantum histories and the forced decoherence of a macroscopic subsystem from its immediate environment [3.1] would theoretically generate a cascade failure—manifesting as topological singularities, or "computational defects," within the symplectic volume form $\tilde{\sigma}$ [9.1]. If left uncompensated, the propagation of these phase defects would introduce non-linear quantum noise, leading to the local destruction of the affine connection metric Γ^i_{jk} and, ultimately, a systemic halt command within adjacent sectors of the spatial matrix [1.1, 9.1].

4.2. The Topological Security Framework and Hardware-Driven Failsafes

To eliminate the possibility of such a macro-systemic collapse, the universe's processing core must enforce rigid, hardware-driven topological constraints that act as absolute failsafes. The mathematical validity of the CQI-PTG is strictly conditional upon its compliance with the global conservation laws derived from the exterior calculus of differential forms [9.1]:

1. **The Symplectic Rigidity Bound:** According to the absolute closure of the fundamental 2-form, $d\tilde{\omega} = 0$, any local deformation of the phase space grid generated by the non-local transition operator must be perfectly symmetrical [1.1, 9.1]. The exact informational volume subtracted from the coordinate domain $A(q_A)$ must identically match the volume re-indexed at the destination $B(q_B)$, satisfying the infinite stiffness of the Gromov non-squeezing theorem. This ensures that the global Lie derivative of the volume form remains invariant ($\mathcal{L}_{\vec{X}}\tilde{\sigma} = 0$), rendering the transition completely transparent to the global temporal progression of the system [1.1, 9.1].

2. **The Isentropic Landauer Censorship:** To prevent thermal death or computational freezing via the dissipation of Landauer heat ($\Delta Q = k_B T \ln 2$), the CQI-PTG operates via strictly reversible, non-destructive quantum mappings [1.1]. By constraining the field transition trajectory to an isentropic hypersurface parameterized by the Caratheodory theorem ($dS = 0$), the internal entropy threshold remains unperturbed [1.1, 9.1].

3. **Ertel-Helmholtz Vector Alignment:** The stability of the materialization process is governed by the conservation of the scalar Ertel invariant α. The device cannot randomly synthesize a physical state; it must accurately reconstruct the exact numerical value of $\alpha = \frac{1}{\rho}\nabla S \cdot (\nabla \times V)$ at the target point B [9.1]. Because α commutes with the temporal progression operator, the transition is processed not as a forbidden quantum transition or coordinate discontinuity, but as an adiabatic, pre-calculated solution to the coordinate-free Euler-Lagrange flow [1.1, 9.1].

4.3. Concluding Remarks

Ultimately, this resolves the conceptual tension between the technological initialization of non-local transitions and the rigid constraints of a superdeterministic universe. The CQI-PTG does not violate the macro-event crystal of the scanning automation; rather, the device can only be successfully initialized at specific spacetime coordinates where the pre-existing global topology of the phase space bundle T^*M already contains a valid, analytical trajectory for non-local mapping [1.1, 9.1]. If an operator attempts to activate the device within a topologically forbidden sector—where the $U(1)$ phase connection is non-continuous or where it violates the closed loop condition of the Maxwell field ($dF \neq 0$)—the system naturally enforces a topological censorship constraint, and the local wave function collapses into a null state [3.1, 9.1].

As noted by 't Hooft, constructing a valid quantum Hamiltonian from a classical deterministic model often requires the inclusion of non-perturbative gravitational structures, which naturally resolve mathematical divergences and energy bounds [10.1]. Our model addresses this challenge directly, proving that the discrete, invariant evolution of S-events provides an elegant, structured foundation that withstands standard academic criticisms [11.1]. Space, time, and matter are emergent illusions of a unified, error-correcting cosmic invariant.

4.4. Experimental Testability and Falsifiability

To satisfy Popper's criterion of falsifiability, the scanning quantum automation model provides a concrete, empirically verifiable prediction. Because the spatial matrix expansion is mathematically formalized as a discrete arithmetic summation of fundamental bits, the sequential state transitions at the Planck scale must induce a non-zero, irreducible phase jitter.

Unlike smooth, continuous spacetime manifolds, this discrete informational scanning creates a specific holographic noise spectrum within the high-frequency band of laser interferometers (such as a Holometer configuration). If precise cross-correlation measurements of orthogonal spacetime volumes do not detect a characteristic Planckian informational noise floor at frequencies near 10^{43} Hz, the core deterministic scaling relation:

$$dS = v(t)\, dt \tag{1}$$

will be strictly falsified.

References

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